C. COASTAL CALIFORNIA METEOROLOGY

California Coastal Waters have been defined as that area between the California coastline and a line starting at the California - Oregon border at the Pacific Ocean

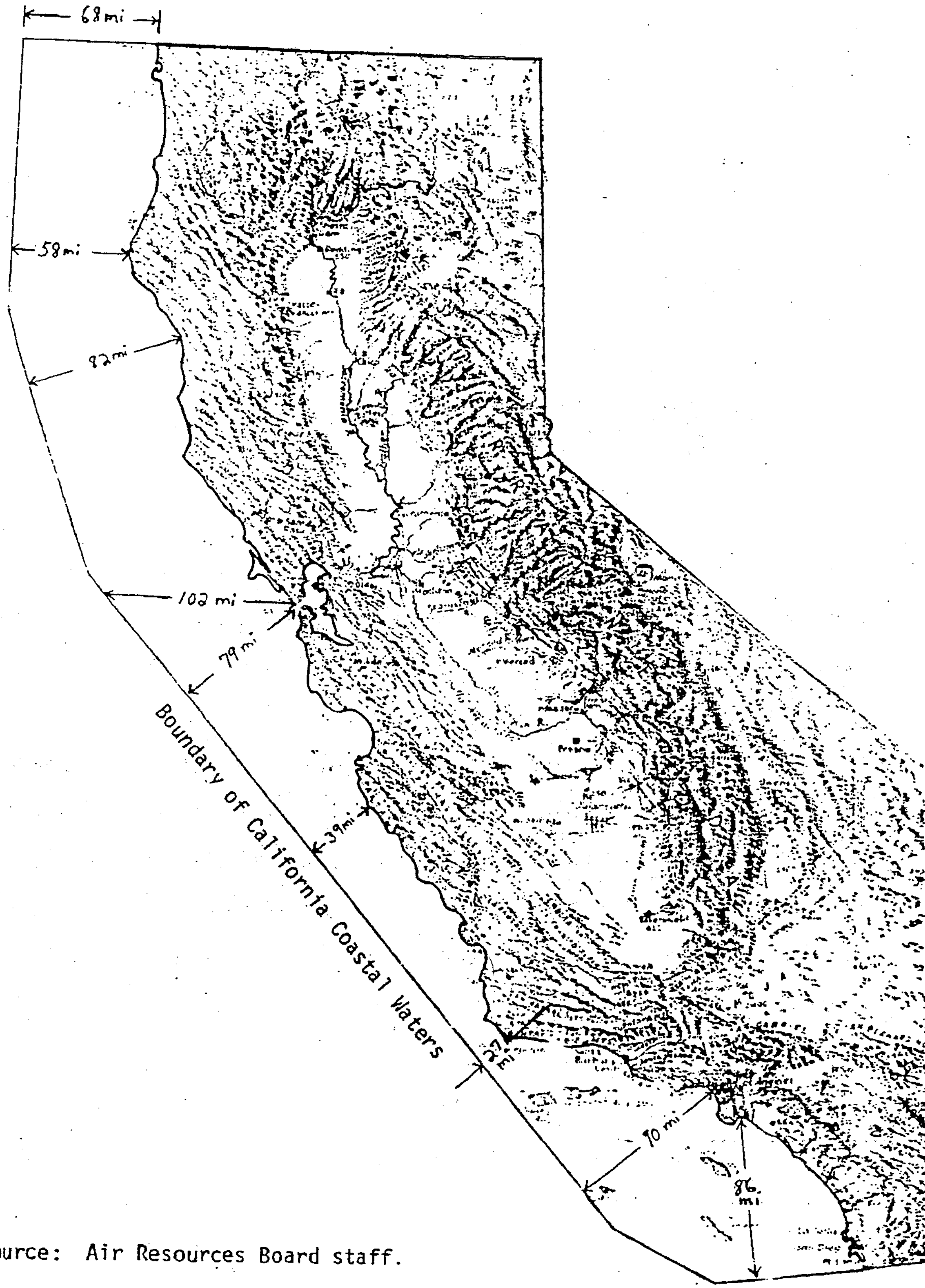
thence to 42.0° 125.5°W
thence to 41.0°N 125.5°W
thence to 40.0°N 125.5°W
thence to 39.0°N 125.0°W
thence to 38.0°N 124.5°W
thence to 37.0°N 123.5°W
thence to 36.0°N 122.5°W
thence to 35.0°N 121.5°W
thence to 34.0°N 120.5°W
thence to 33.0°N 119.5°W
thence to 32.5°N 118.5°W

and ending at the California-Mexico border at the Pacific Ocean. The California Coastal Waters are shown on Figure VI-6.

The line describing California Coastal Waters does not form a political boundary but it is useful in describing the fate of pollutants emitted off the California coast. The definition of California Coastal Waters was developed by the ARB meteorology staff and was originally presented as Appendix A to the ARB staff report, Status Report Regarding Adoption by Local Air Pollution Control Districts of Rules for the Control of Emissions from Lightering Operations, February 23, 1978. California Coastal Waters as defined above is the area offshore of California within which pollutants are likely to be transported ashore and affect air quality in California's coastal air basins, particularly during the summer. Pollutant emissions released somewhat to the west of these waters in summer are likely to be transported southward, parallel to the coast. Most coastal marine traffic passes 3 to 15 miles from

FIGURE VI-6

CALIFORNIA COASTAL WATERS



Source: Air Resources Board staff.

the coast, well within the boundaries of California Coastal Waters. Emissions released well west of these waters are likely to be transported southwestward, away from the coast.

Development of the definition of California Coastal Waters is based on over 500,000 island, shipboard, and coastal meteorological observations. These data were taken from official records of a number of agencies including the U.S. Weather Bureau, Coast Guard, Navy, Air Force, Marine Corps, Civil Aeronautics Administration and Army Air Force (see pages 11 and 12 of Appendix H-1).

> WOGA Comment: WOGA does not accept the State's definition of California Coastal Waters for the reasons outlined in its legal position paper in Appendix B.

The development of the definition for California Coastal Waters is discussed in detail in Appendix H-1. The primary meteorological features of the California coastal areas that cause pollutants emitted within California Coastal Waters to be transported ashore are discussed below.

1. Pacific High Pressure Cell

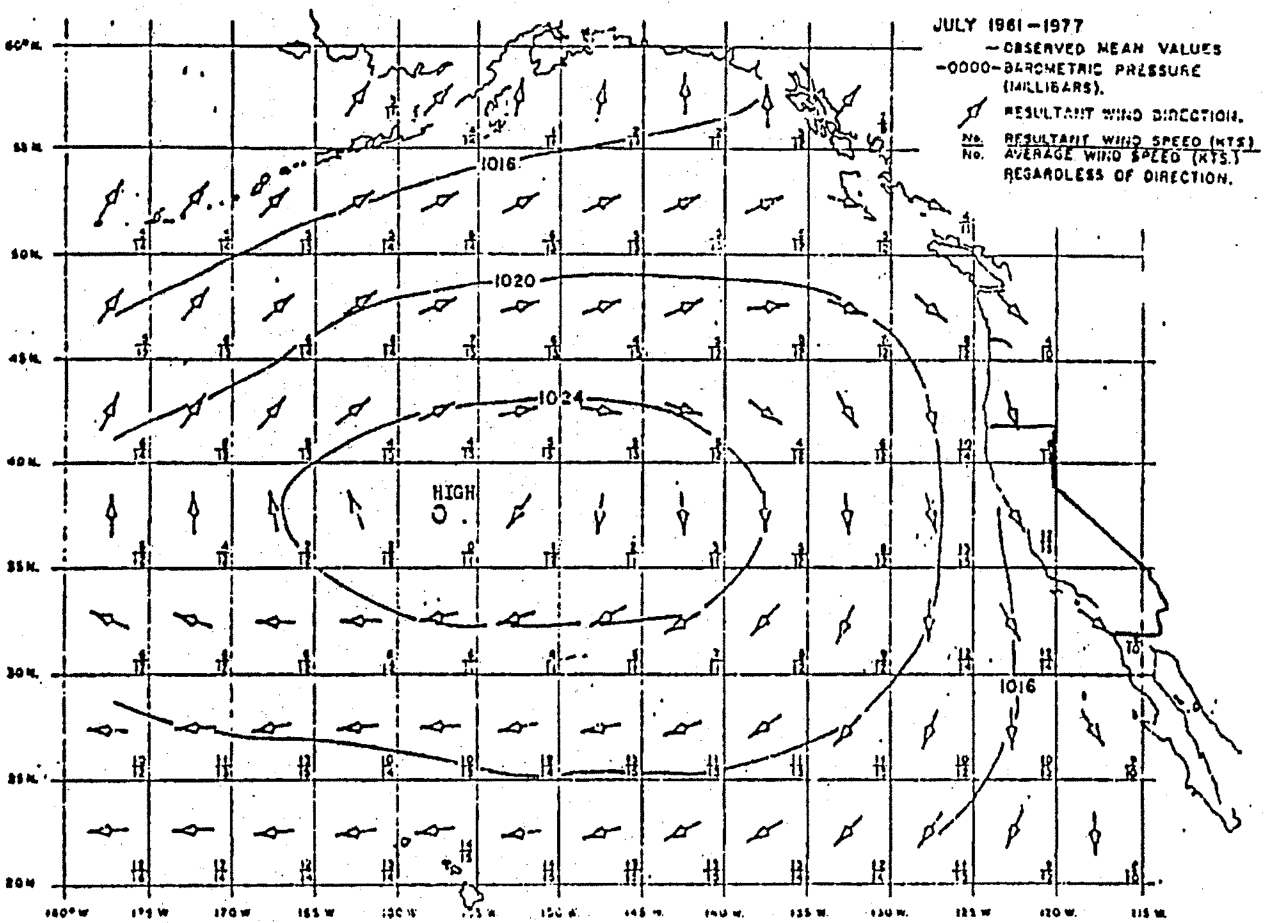
The North Pacific high pressure cell (anticyclone) is the dominant influence on the weather and climate of the eastern North Pacific Ocean and neighboring land areas in middle latitudes, particularly during the summer. It is a semi-permanent feature of the large scale atmospheric circulation pattern in the northern hemisphere and consists of an extensive deep mass of air rotating in a clockwise direction and covering much of the North Pacific Ocean throughout the year.[27/]

The basic cause of this circulation feature is the large scale thermal difference between adjacent water and land masses in middle latitudes.[27/] During summer, the water mass is much cooler than the neighboring land mass.

Through conduction and mixing, the air above the water is cooled and its density is increased thus producing a vast high pressure cell. In addition, air from the Equator enters the system aloft to provide additional support for high pressures. East of the ocean, the warm land increases the air temperature and consequently the air becomes less dense resulting in the formation of a large low pressure cell or thermal low. The positive differential of pressure from ocean and land causes a gigantic interchange of air. The warming air above the land surfaces rises and is replaced at low levels by cooler air moving onshore from the Pacific Ocean. A further interchange takes place aloft where air sinks in the Pacific high to replace the air that moved onshore. The sinking air in turn is replaced aloft by air from the tropics.

Because sinking (subsiding) air over the ocean is warmed by compression, it becomes warmer at lower levels than the air in the marine layer next to the ocean surface. The subsidence thus produces a strong persistent vertical temperature inversion which is another dominant feature of the Pacific high.[27/]

The Pacific high is strongest and most extensive in the summer when the temperature difference between the ocean and land is greatest. As the seasons progress and the sun moves southward, this ocean-land thermal discontinuity lessens and is displaced to more southerly latitudes as northern lands cool. This tends to weaken the Pacific high cell and causes it to move southward. The arrival of winter storms in middle latitudes also keeps the Pacific high somewhat suppressed thus reducing its influence in middle latitudes during winter.[27/] The average extent and location of the North Pacific anticyclone for the mid-summer and mid-winter months of July and January (seasonal extremes) are shown in Figures VI-7 and VI-8 respectively.

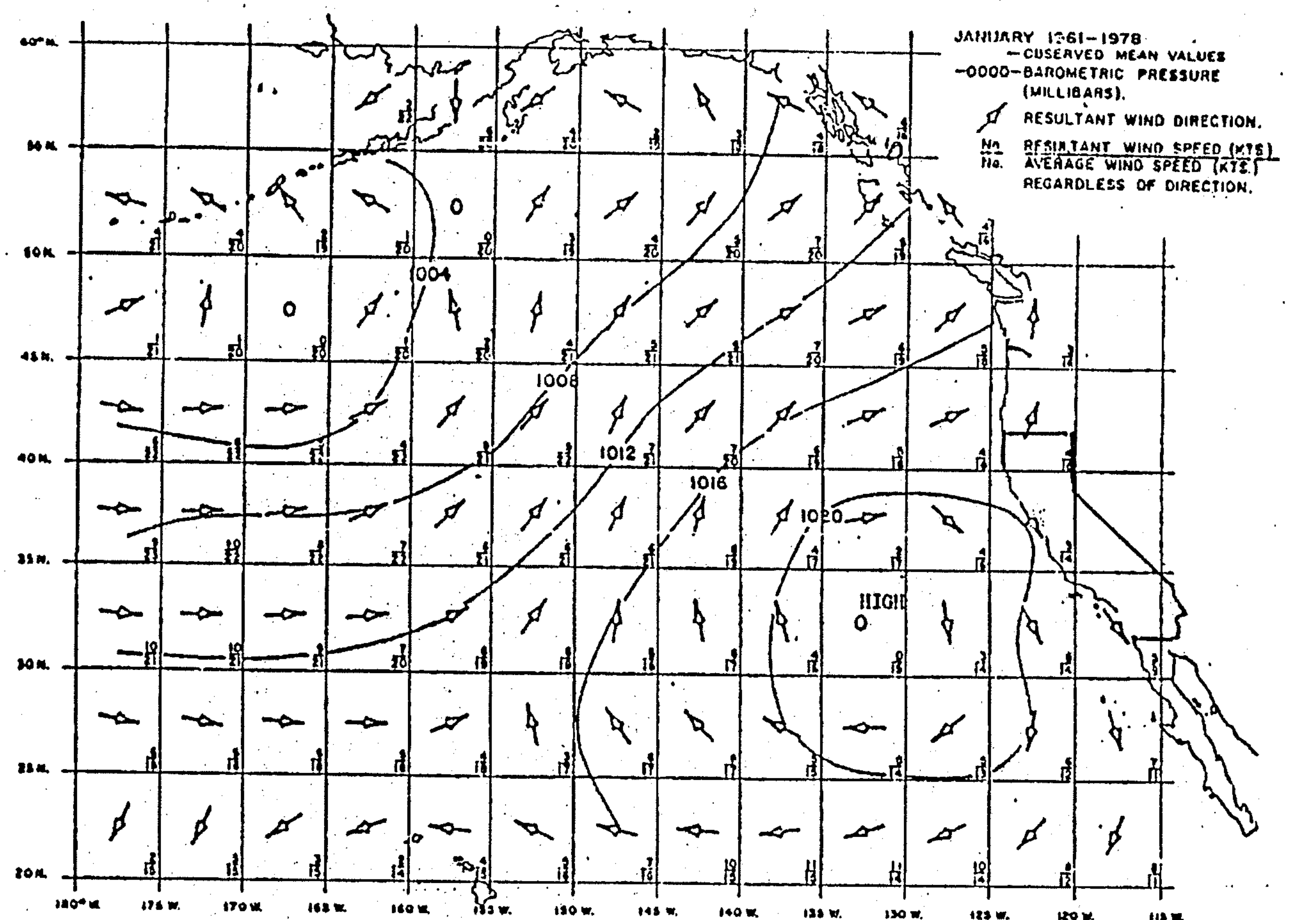


Mean July location of the Pacific High Pressure Cell. Resultant winds are shown for each 5° latitude and 5° longitude area. The wind speed numbers in the lower right hand corner of each area can be divided to obtain the steadiness ratio. Ratios between 0.7 and 0.9 (such as those found off the California coast) indicate the resultant winds are representative. Low ratios (such as those found near the center of the high cell) indicate that the individual winds varied markedly from the resultant wind direction.

FIGURE VI-7

MEAN JULY LOCATION OF THE PACIFIC HIGH PRESSURE CELL

Source: National Marine Fisheries Service, July 1977.



Mean Jan. location of the Pacific High Pressure Cell. Resultant winds are shown for each 5° latitude and 5° longitude area. The wind speed numbers in the lower right hand corner of each area can be divided to obtain the steadiness ratio. Ratios between 0.7 and 0.9 (such as those found off the California coast) indicate the resultant winds are representative. Low ratios (such as those found near the center of the high cell) indicate that the individual winds varied markedly from the resultant wind direction.

FIGURE VI-8

MEAN JANUARY LOCATION OF THE PACIFIC HIGH PRESSURE CELL

Source: National Marine Fisheries Service, January 1978.

2. Coastal California Predominant Wind Flows

The North Pacific high pressure cell produces a predominantly northwesterly flow of marine air over California Coastal Waters. This large scale circulation pattern is modified to a more westerly flow by continental influences as the air approaches the coast of California.[27/] Table VI-5 presents a summary of windflow direction frequencies measured at various locations along the California coast. The table shows that onshore windflows predominate during the spring, summer, and fall at all locations. The table also shows that the percentage frequency of offshore winds exceeds onshore winds in the winter at Vandenburg Air Force Base, Point Mugu, and Los Angeles. The greater overall frequency of onshore winds indicates a net transport of marine air, including the pollutant content of such air, into coastal air basins. This can be seen graphically in Figures VI-9 and VI-10 which show the predominant summer wind flow patterns along the coast of northern California and southern California respectively.

3. Land/Sea Breezes

The large scale climatological wind flows along the California coast as discussed above are modified by the effects of local land/sea breeze circulations. In effect, the local daytime sea breeze enhances the large-scale onshore component of the wind while the nighttime land breeze retards or on occasion reverses the flow.[28/] Table VI-6 presents seasonal resultant winds by time of day for Oakland and Point Mugu Naval Air Station (NAS) located just south of Oxnard. The table shows the influences of the land/sea breeze circulations and shows that the onshore winds are generally stronger than offshore winds, a further indication of the transport of

TABLE VI-5

Windflow Direction Frequencies in Coastal Areas of California

Station	Direction of Wind Flow	Seasonal Frequency in Percent				
		Spring[a]	Summer[b]	Fall[c]	Winter[d]	Annual
Oakland	Onshore	75%	83%	62%	47%	67%
	Offshore	20%	13%	27%	42%	25%
	Calm	5%	4%	11%	11%	8%
Vandenberg AFB	Onshore	64%	69%	48%	34%	54%
	Offshore	24%	9%	32%	53%	29%
	Calm	12%	22%	20%	13%	17%
Santa Barbara	Onshore	50%	62%	44%	32%	47%
	Offshore	26%	21%	29%	24%	25%
	Calm	24%	17%	27%	44%	28%
Point Mugu NAS	Onshore	57%	59%	41%	31%	47%
	Offshore	28%	21%	41%	54%	36%
	Calm	15%	20%	18%	15%	17%
Los Angeles	Onshore	68%	81%	60%	43%	63%
	Offshore	30%	16%	36%	53%	34%
	Calm	2%	3%	4%	4%	3%

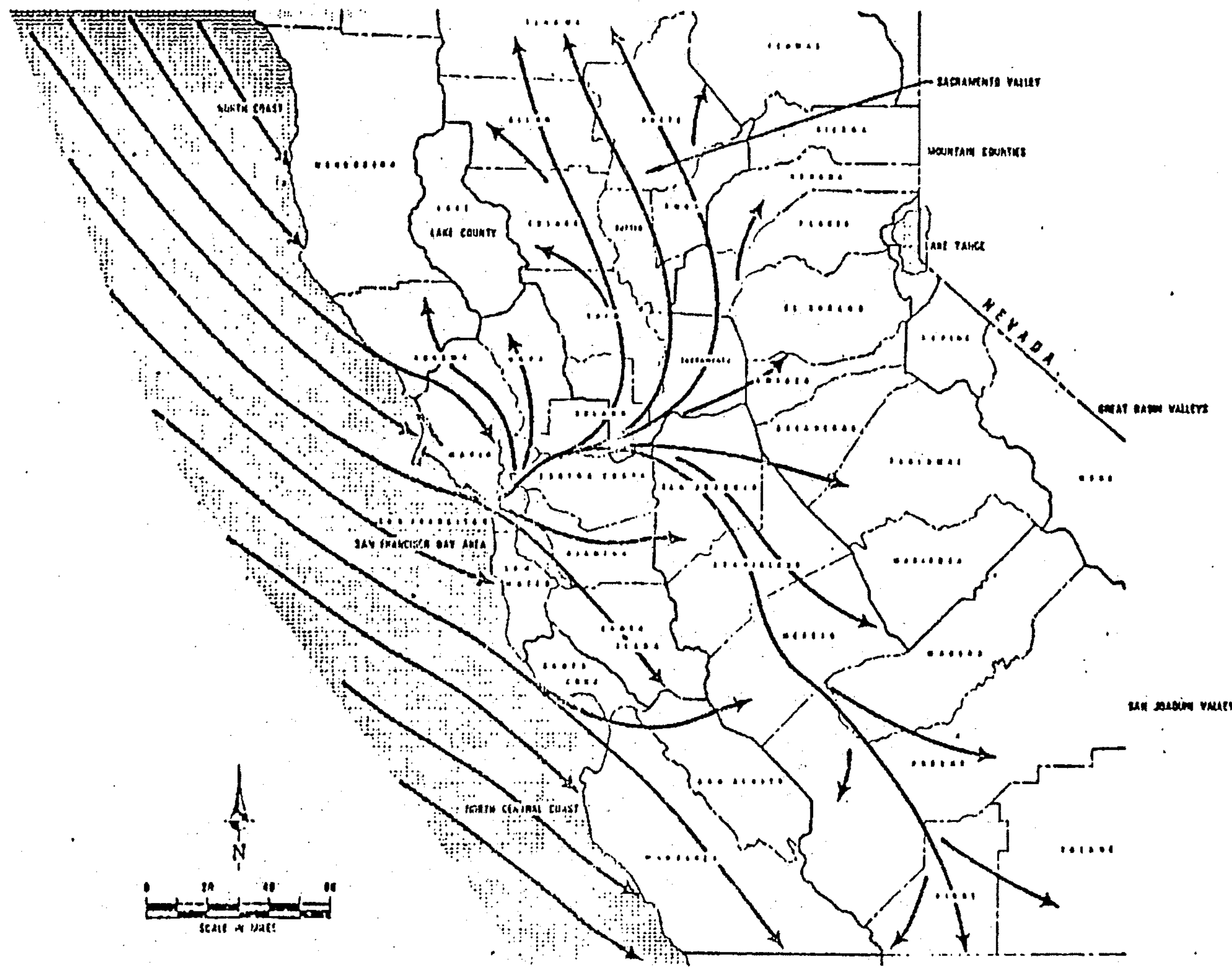
Period of Record: Oakland 1965-1978
Vandenberg AFB 1959-1977
Santa Barbara 1960-1964
Point Mugu NAS 1960-1972
Los Angeles International 1960-1978

[a] Spring: March, April, May
[b] Summer: June, July, August
[c] Fall: September, October, November
[d] Winter: December, January, February

Source: National Climatic Center

FIGURE VI-9

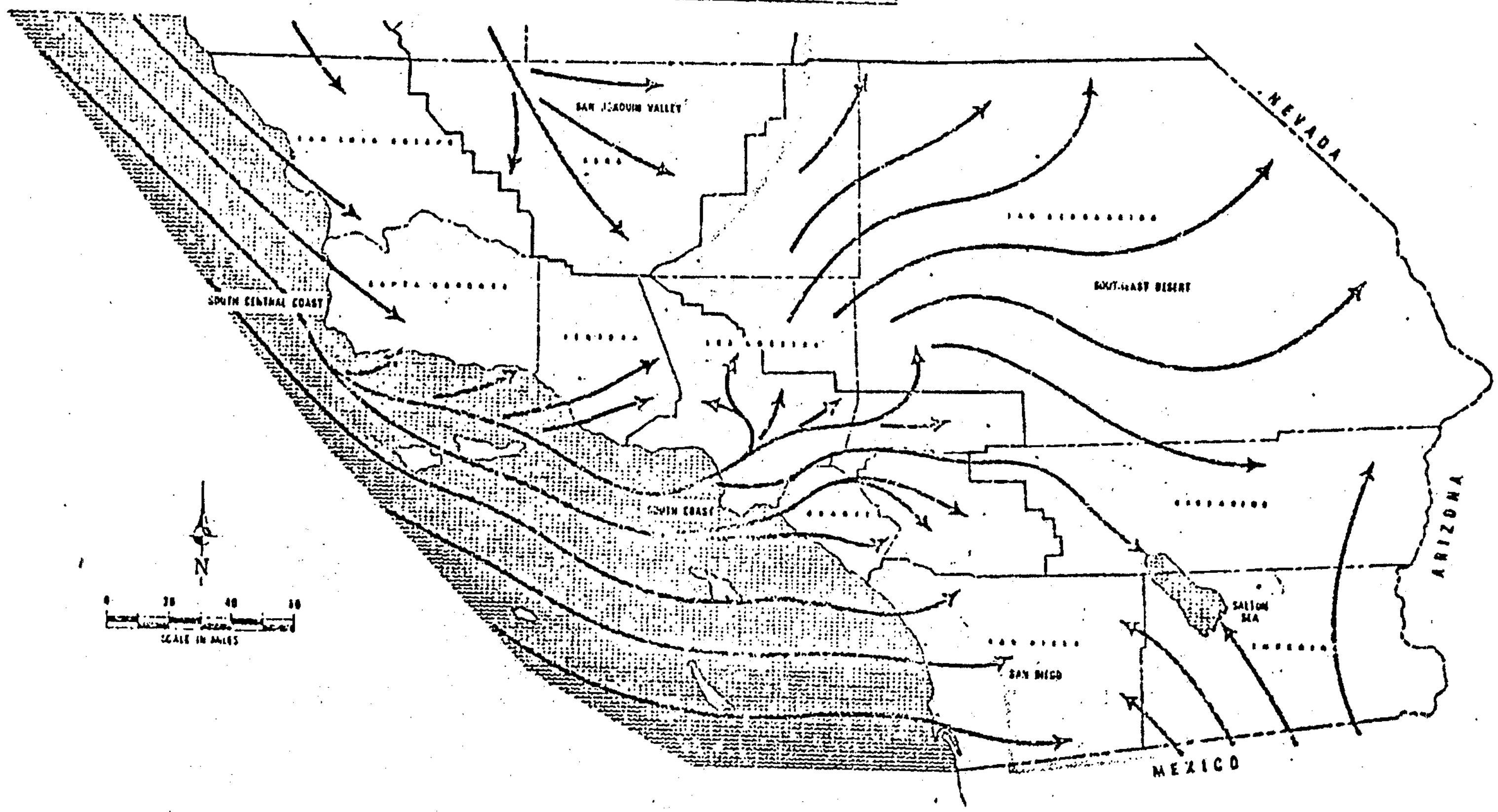
NORTHERN CALIFORNIA
PREDOMINANT WIND FLOW PATTERNS
SUMMER (JUNE, JULY, AUGUST)



Source: Air Resources Board Technical Services Division

FIGURE VI-10

SOUTHERN CALIFORNIA
PREDOMINANT WIND FLOW PATTERNS
SUMMER (JUNE, JULY, AUGUST)



Source: Air Resources Board, Technical Services Division

TABLE VI-6

Three-Hourly and Seasonal Resultant Winds
(Degrees/MPH - Onshore Winds in Parens)

Oakland

Time (PST)	Spring	Summer	Fall	Winter	Annual
0100	(270/4)	(280/6)	(300/1)	100/2	(280/2)
0400	(270/2)	(280/5)	020/1	100/2	(280/1)
0700	(230/1)	(270/4)	120/1	110/3	(220/1)
1000	(250/5)	(270/7)	(240/3)	150/2	(250/4)
1300	(270/9)	(290/11)	(280/7)	(260/4)	(280/8)
1600	(280/12)	(290/13)	(290/3)	(280/4)	(280/9)
1900	(280/9)	(290/11)	(300/6)	(320/1)	(290/7)
2200	(230/6)	(280/7)	(300/3)	080/1	(290/4)
All Hours	(270/6)	(280/8)	(280/4)	(190/1)	(280/4)

Point Mugu NAS

Time (PST)	Spring	Summer	Fall	Winter	Annual
0100	323/1	Calm	036/2	033/4	024/1
0400	007/1	029/1	032/2	036/4	030/2
0700	013/2	013/1	031/2	038/4	029/2
1000	(230/4)	(235/5)	(210/1)	052/4	(230/2)
1300	(250/8)	(252/8)	(248/5)	(230/2)	(249/6)
1600	(264/9)	(257/8)	(259/6)	(279/3)	(268/7)
1900	(279/5)	(287/4)	320/2	001/2	(297/3)
2200	(297/2)	(291/1)	002/2	022/3	340/2
All Hours	(269/3)	(264/3)	(301/1)	022/2	(288/2)

Period of Record: Oakland 1975-1979
Point Mugu 1962-1977

Source: National Climatic Center

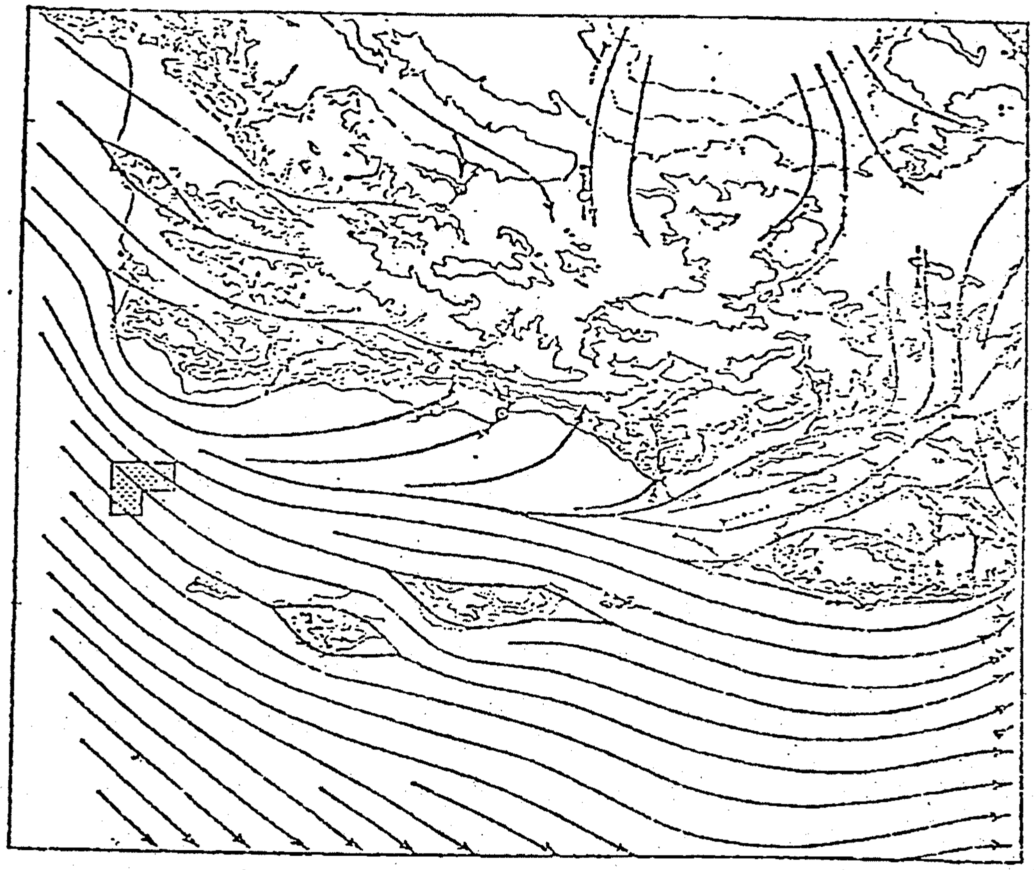
offshore emissions to receptor areas onshore. The table also shows that the fall and winter resultant winds, whether onshore or offshore, are not strong winds, having resultant magnitudes less than 7 miles per hour at the coast at all times.

4. Windflows in the Santa Barbara Channel

Analyses of airflow patterns in the Santa Barbara Channel indicate that emissions in the Channel that are not transported to the Santa Barbara or Ventura County coasts are carried into the South Coast Air Basin.[28/] Figures VI-11 through VI-14 were presented to the California Coastal Commission on October 23, 1982, as part of Chevron U.S.A.'s testimony on the determination of consistency with the Coastal Zone Management Act for proposed exploratory oil wells that Chevron proposes to drill in the Santa Barbara Channel. The figures present the airflow patterns in the Santa Barbara Channel for daytime and nighttime in both winter and summer. Figures VI-11 and VI-12 show that the daytime airflows, both in summer and winter, will transport emissions in the Channel either to Santa Barbara or Ventura County, or to the South Coast Air Basin. Figures VI-13 and VI-14 show that the nighttime windflows in the Channel tend to carry emissions into Ventura County or into the Gulf of Santa Catalina off the South Coast Air Basin. The pollutants arriving in the Gulf of Santa Catalina can be carried into the Los Angeles area as the nighttime land breeze is replaced by the daytime sea breeze.

5. Atmospheric Inversion

The air that flows around the Pacific high at upper levels sinks (subsides) and consequently warms due to air compression. This warm air above the cool coastal marine air produces a strong and persistent vertical temperature inversion that is a major influence on atmospheric stability.



JULY 1200–1800 PST

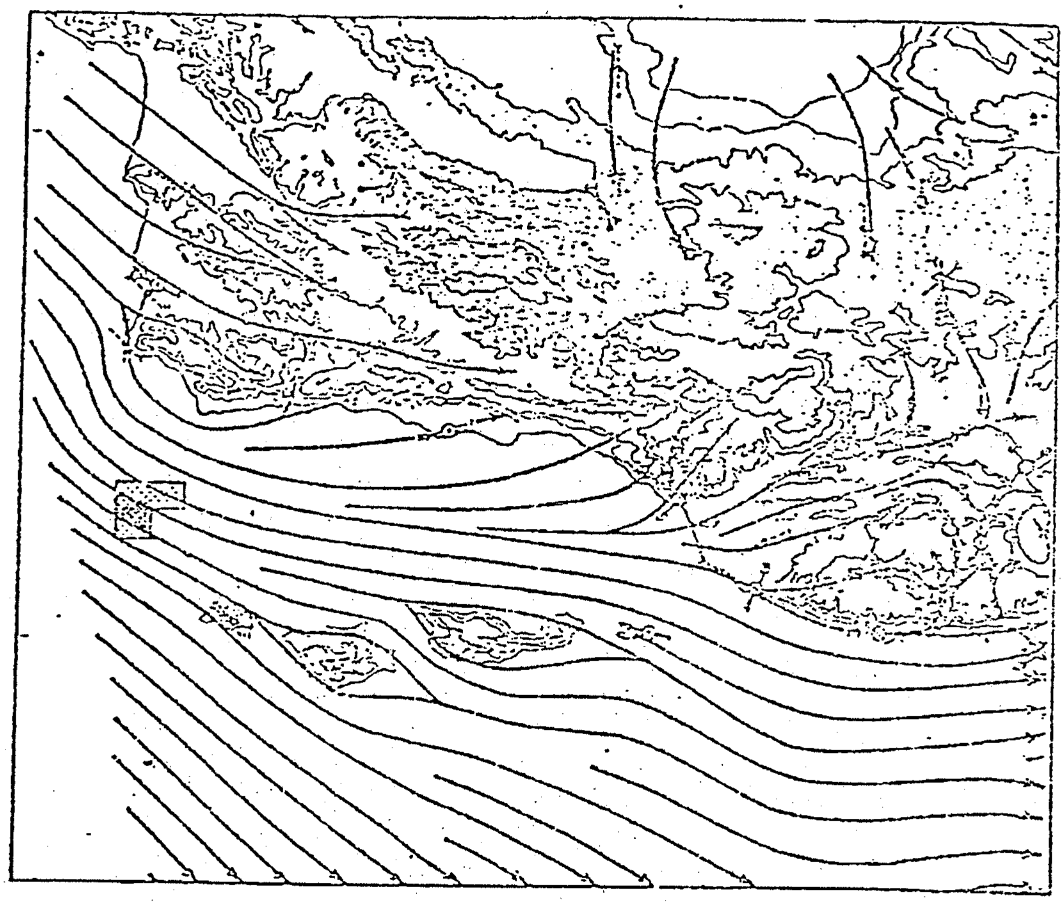
CHEVRON LEASES P-0331, P-0332, AND P-0338

FIGURE VI-11

DAYTIME AIRFLOW IN THE SANTA BARBARA CHANNEL

SUMMER

Source: Meteorological Summaries Pertinent to Atmospheric Transport and Dispersion Over Southern California, Technical Paper No. 54, G. A. DeMarrais, G. D. Holzworth, and C. R. Holser, U.S. Department of Commerce, 1965. Taken from the testimony of Valerie Brown, Chevron, U.S.A., during the consistency hearings of the California Coastal Commission on Chevron U.S.A.'s exploratory wells on leases P-0331, P-0332, and P-0338, October 22, 1981.



JANUARY 1200–1700 PST

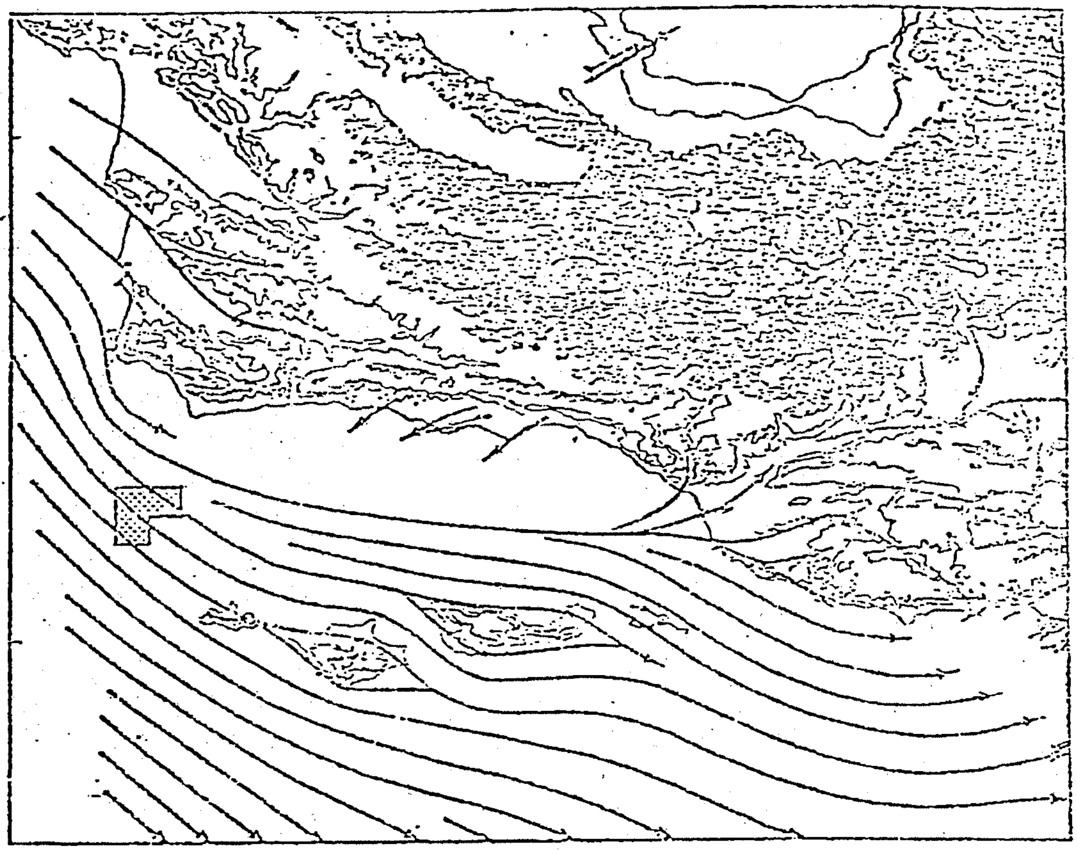
CHEVRON LEASES P-0331, P-0332, AND P-0338

FIGURE VI-12

DAYTIME AIRFLOW IN THE SANTA BARBARA CHANNEL

WINTER

Source: Meteorological Summaries Pertinent to Atmospheric Transport and Dispersion Over Southern California, Technical Paper No. 54, G. A. DeMarrais, G. D. Holzworth, and C. R. Holser, U.S. Department of Commerce, 1965. Taken from the testimony of Valerie Brown, Chevron, U.S.A., during the consistency hearings of the California Coastal Commission on Chevron U.S.A.'s exploratory wells on leases P-0331, P-0332, and P-0338, October 22, 1981.



JULY 0000–0500 PST

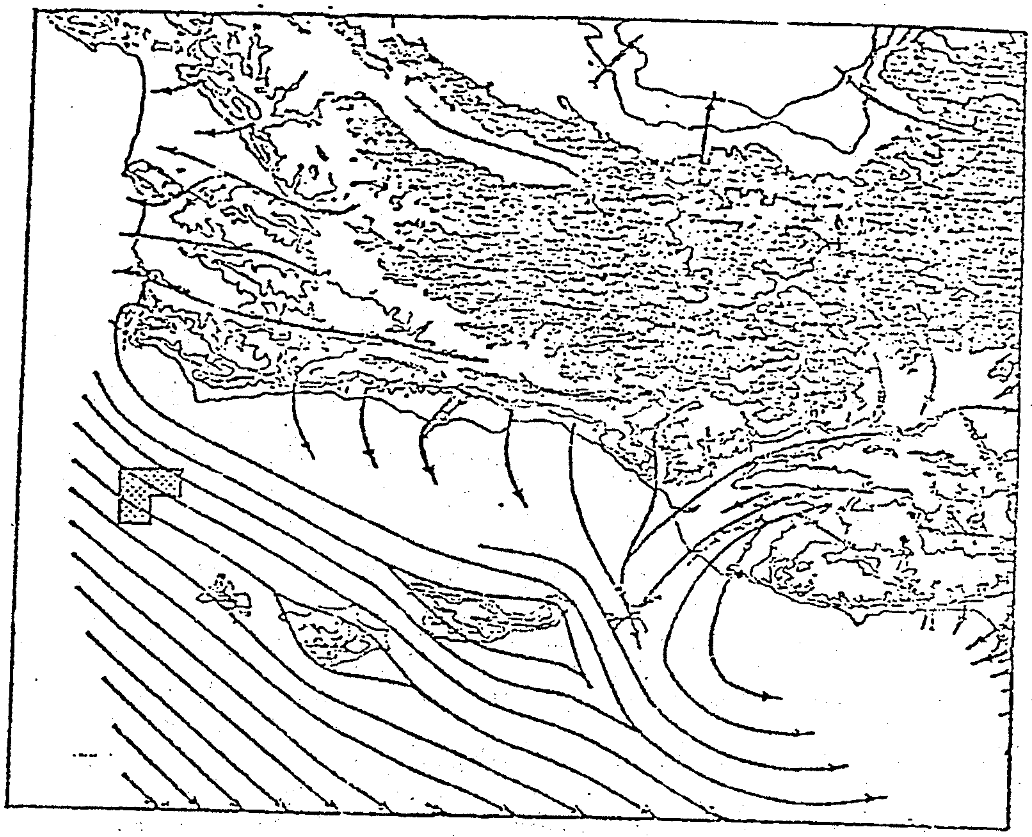
CHEVRON LEASES P-0331, P-0332, AND P-0338

FIGURE VI-13

NIGHTTIME AIRFLOW IN THE SANTA BARBARA CHANNEL

SUMMER

Source: Meteorological Summaries Pertinent to Atmospheric Transport and Dispersion Over Southern California, Technical Paper No. 54, G. A. DeMarrais, G. C. Holzworth, and C. R. Holser, U.S. Department of Commerce, 1965. Taken from the testimony of Valerie Brown, Chevron, U.S.A., during the consistency hearings of the California Coastal Commission on Chevron U.S.A.'s exploratory wells on leases P-0331, P-0332, and P-0338, October 22, 1981.



JANUARY 0000-0700 PST

CHEVRON LEASES P-0331, P-0332 AND P-0338

FIGURE VI-14

NIGHTTIME AIRFLOW IN THE SANTA BARBARA CHANNEL

WINTER

Source: Meteorological Summaries Pertinent to Atmospheric Transport and Dispersion Over Southern California, Technical Paper No. 54, G. A. DeMarrais, G. D. Holzworth, and C. R. Holser, U.S. Department of Commerce, 1965. Taken from the testimony of Valerie Brown, Chevron, U.S.A., during the consistency hearings of the California Coastal Commission on Chevron U.S.A.'s exploratory wells on leases P-0331, P-0332, and P-0338, October 22, 1981.

Atmospheric stability is the primary weather factor that influences the vertical dispersion of pollutants. In general, the more stable the air, the more dispersion is inhibited. An extremely stable subsidence inversion dominates the California coastal areas and effectively caps the marine layer providing a ceiling above which pollutants cannot rise. This reduces the vertical dispersion of air pollution, particularly during the summer when the inversion is strongest and most persistent.[27/]

Table VI-7 is a compilation of seasonal inversion frequencies and characteristics for Oakland, Vandenberg AFB, and Point Mugu NAS. The table shows that the mean height of the base of the subsidence inversion ranges between 600 and 2200 feet above sea level (asl) and is persistent throughout the year (inversions are present some 90 percent of the time). The combination of a strong persistent inversion and the onshore winds which characterize the coastal meteorology of California is conducive to the transport of offshore emissions to coastal air basins. Offshore emissions are ducted beneath or within the inversion, with little dispersion, to onshore areas.

6. Fog

The moisture content of air is another climate-related parameter which must be taken into account when considering coastal air quality. In the presence of suspended water droplets, acid precursors such as sulfur oxides can be transformed into acidic particles. Conversion of sulfur dioxide to acidic particles adversely affects ambient concentrations of sulfate and TSP, contributes to visibility degradation, and contributes to acidification of precipitation, cloud and, fog.

The climatic arrangement of warm stable air over the cool marine environment that dominates the coastal waters of California produces a relatively high incidence of fog.[27/] The frequency of occurrence of fog

TABLE VI-7

Atmospheric Inversion Statistics[a/]
(Composite of 4 a.m. and 4 p.m. Soundings)

Oakland

	Spring	Summer	Fall	Winter	Annual
Mean					
Inversion Top (ft asl)	3200	2800	2900	3000	3000
Inversion Base (ft asl)	2200	1200	1700	1900	1700
Strength (Top Temp-Base Temp)	6°F	15°F	8°F	6°F	9°F
Percentage Occurrence					
Inversion	80%	98%	88%	80%	86%
Base ≤ 3000' asl	58%	94%	71%	60%	71%
Base ≤ 1000' asl	31%	47%	44%	43%	41%

Vandenberg AFB

	Spring	Summer	Fall	Winter	Annual
Mean					
Inversion Top (ft asl)	2900	3200	2700	2600	2900
Inversion Base (ft asl)	1700	1400	1400	1600	1500
Strength (Top Temp-Base Temp)	10°F	20°F	12°F	8°F	13°F
Percentage Occurrence					
Inversion	89%	99%	93%	85%	92%
Base ≤ 3000' asl	77%	96%	85%	71%	83%
Base ≤ 1000' asl	40%	32%	50%	55%	44%

Point Mugu NAS

	Spring	Summer	Fall	Winter	Annual
Mean					
Inversion Top (ft asl)	1900	2800	2000	1400	2100
Inversion Base (ft asl)	1100	1300	1000	600	1000
Strength (Top Temp-Base Temp)	7°F	14°F	10°F	8°F	10°F
Percentage Occurrence					
Inversion	84%	99%	96%	87%	92%
Base ≤ 3000' asl	73%	93%	86%	83%	84%
Base ≤ 1000' asl	57%	47%	66%	68%	59%

a/ Period of Record: 1975-1977

Source: Summary of California Upper Air Meteorological Data, Air Resources Board.

(visibility less than 7 miles) at Alameda NAS and Point Mugu NAS, is shown in Figure VI-15. As indicated in the figure, fog is frequent during the night and early morning hours, especially during the cold half of the year in the Bay area and during the warm half of the year in the Southern California area. In the latter case, fog is observed more than 50 percent of the time around sunrise at Point Mugu NAS. Considering all hours and seasons, fog is present on about 25 percent of the days at Alameda and on 40 percent of the days at Point Mugu.

D. TRACER STUDIES

Tracer studies are conducted by releasing known quantities of a readily detectable, inert gas into the atmosphere and sampling the atmosphere for concentrations of that gas in areas to which an air parcel could be expected to be transported. The characteristics of the transport and dispersion of air pollutants and wind patterns can thus be discerned by the tracer concentrations in the samplings.

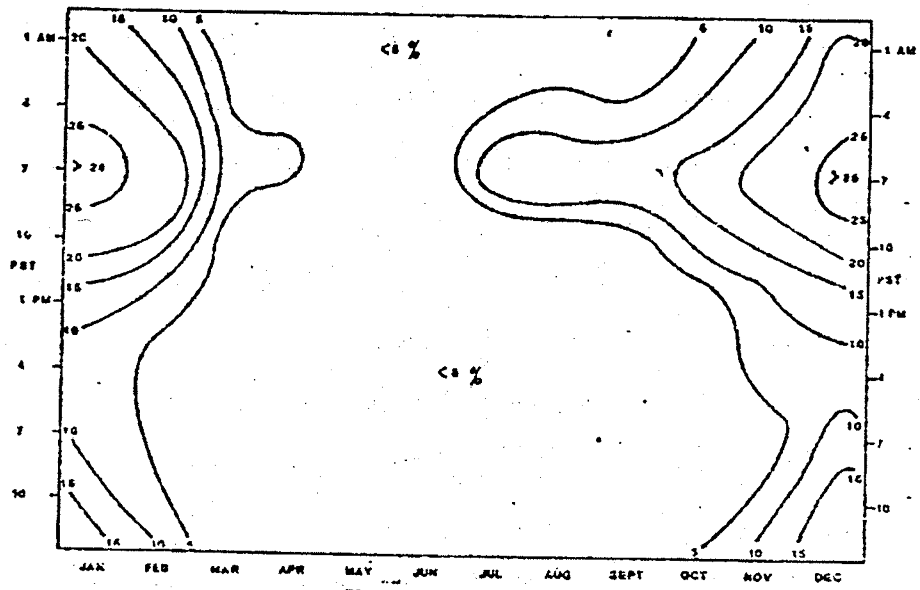
During September and October 1980, Meteorology Research, Inc. (MRI), and investigators from the California Institute of Technology (Caltech) conducted tracer studies in the Santa Barbara Channel area.[29/] A detailed summary of those tests is appended to this report as Appendix H-2. The appendix consists of the first fifteen pages of the report, Tracer Investigations of Atmospheric Transport Into, Within, and Out of the Santa Barbara Channel and the Coastal Areas of Santa Barbara and Ventura Counties, January 15, 1981.

The MRI/Caltech tracer studies were performed by conducting six releases of sulfur hexafluoride (SF_6) as the tracer gas in and around the Santa Barbara channel area. Over 2,240 hourly-averaged samples, obtained at fixed sites along the coast and inland, and about 10,000 grab samples obtained during traverses by automobiles, airplanes, and boats were collected during the studies.

FIGURE VI-15

PERCENTAGE OF OBSERVATIONS REPORTING FOG
(Visibility Less Than 7 Miles)

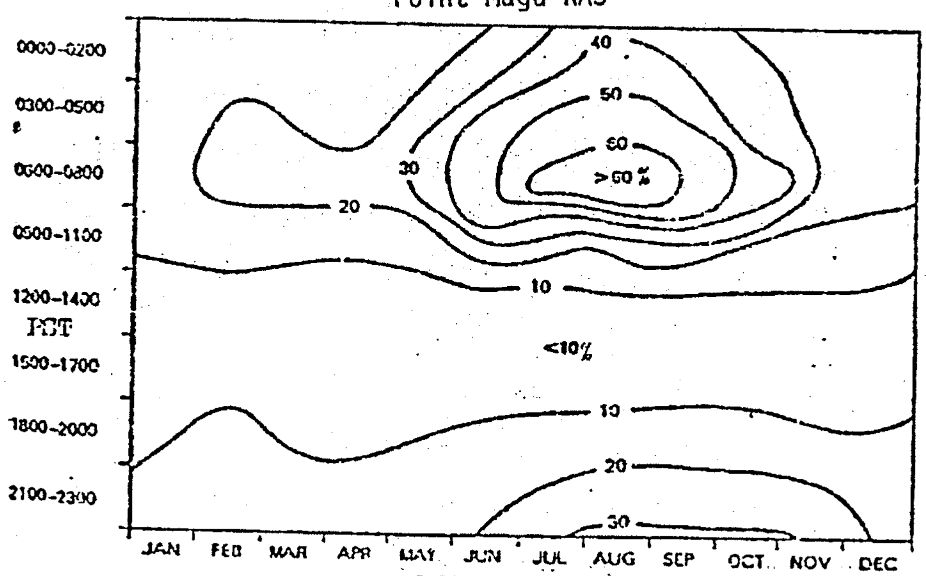
Alameda NAS



FREQUENCY OF FOG

Source: National Climatic Center

Point Mugu NAS



FREQUENCY OF FOG

Source: Climatic Handbook for Point Mugu and San Nicolas Island, Par Surface Data, Pacific Missile Range Report by Robert de Violi March 1974.

The general aspects of the transport and dispersion were remarkably consistent from test to test. During each test, a major portion of the tracer cloud was transported efficiently onshore by the afternoon sea breeze. The transport of pollutants released from the Point Conception region was influenced by an eddy centered around Gaviota. This eddy transported the tracer material in a counter-clockwise motion into the middle of the channel, and then back to the coastal zone east of El Capitan. Over the water, the tracer was transported long distances with very little dispersion in the vertical direction. In one case, for example, the tracer was transported downwind over 60 kilometers (40 miles), but spread only 150 meters (500 feet) vertically. Such results clearly indicate that pollutant emissions from sources located in California Coastal Waters result in downwind concentrations of those pollutants onshore. In addition, these tracer releases indicate that the air over the ocean is substantially more stable than over land.

A second general feature observed is that the diurnal reversals of wind direction associated with a land-sea breeze circulation system can cause offshore pollutants to persist in the coastal area for long periods of time. For example, in one test the tracer was released over a five-hour period, and the tracer material was detected at onshore sampling stations located along a coastal distance exceeding 50 miles. The tracer was detected in the coastal region for over 19 consecutive hours. Persistence, as indicated by these results, appears to be a characteristic of offshore plumes dispersed under the conditions of diurnal reversals in wind direction. Such conditions occur frequently along the entire California coast.

These tests show that, during meteorological conditions that existed during the tracer releases, pollutants emitted virtually anywhere in the Santa Barbara Channel will be transported onshore. The tracer tests also indicate that, during those meteorological conditions, very little dispersion occurs over water in the vertical direction and, as a consequence, pollutant concentrations downwind will be elevated. The "flow reversals" which commonly occur between offshore and onshore winds indicate that pollutants released in the Channel can persist for long periods in the coastal area. At this time, it has not been determined how far inland the pollutants emitted into the Channel can be transported. However, a study by Drivas and Shair[30/] has confirmed that atmospheric transport occurs from the Oxnard Plain (Coast of Ventura) into the San Fernando Valley of the South Coast Air Basin.

In 1977, a tracer study was conducted in and around the Santa Monica Bay to determine the fate of emissions from coastal sources in the characteristic diurnal circulation system in the South Coast Air Basin.[31/] SF_6 was released from a stack at Southern California Edison Company's El Segundo Generating Station beginning at midnight on July 22, 1977, and ending at 5:00 a.m. that day. The release of a total of 90 kilograms of SF_6 was made during the nighttime land breeze. Monitoring stations along the coast began to detect the tracer gas being transported back to shore as early as 8:00 a.m. on July 22. Mass balance calculations further showed that the daytime sea breeze had transported all of the tracer material back across the coastline by 4:00 p.m. on that same day. The study shows the occurrence of net positive transport of "fresh" marine air into the air basin despite the diurnal circulation system, as well as showing the recycling of pollutants from the land mass to sea, and back to land during the sea breeze-land breeze regime.

Another study conducted in 1977 involved the use of dual tracers. This study was designed to determine the onshore impact region of emissions from vessels operating along shipping lanes off the South Coast Air Basin and in the Santa Barbara Channel. The tracer releases were made from the U.S. Naval Postgraduate School Research Vessel "Acania" as it moved along the northwest-bound shipping lane between Long Beach and Santa Barbara. The path of the "Acania" as releases were made is shown in Figure VI-16. A sampling network was established along a section of the coast between Long Beach and Ventura. Twenty-nine sites were chosen to locate hourly-average samplers. The locations of those sites are shown in Figure VI-17.

The study started on July 26, 1977, with dual tracer gas releases at 0530 PDT near Long Beach and was terminated at 1730 PDT in the Santa Barbara Channel. Sulfur hexafluoride (SF_6) was released at the rate of 80 lbs/hr during the entire test as the research vessel proceeded northwest from Long Beach to the Santa Barbara Channel 8 to 20 miles offshore. Bromotrifluoromethane ($CBrF_3$) was released at 50 lbs/hr between 0530-0830 PDT at the start of the test and again between 1230-1730 PDT on the last segment of the route. These two segments are shown as cross-hatched areas on Figure VI-16.

Both tracer gases were detected at sampling stations along the entire length of the sampling network. The bulk of the tracer gases began to be detected about 0900 PDT following the onset of the sea breeze. The measured concentrations were used in preliminary calculations to provide estimates that significant amounts of both tracer gases released offshore returned across the coast between the sampling network and the top of the mixed layer.

The results of this tracer test support the results of other tracer studies and the analyses of historical climatological data that show the transport of offshore emissions to onshore areas most of the time, and particularly during the summer.

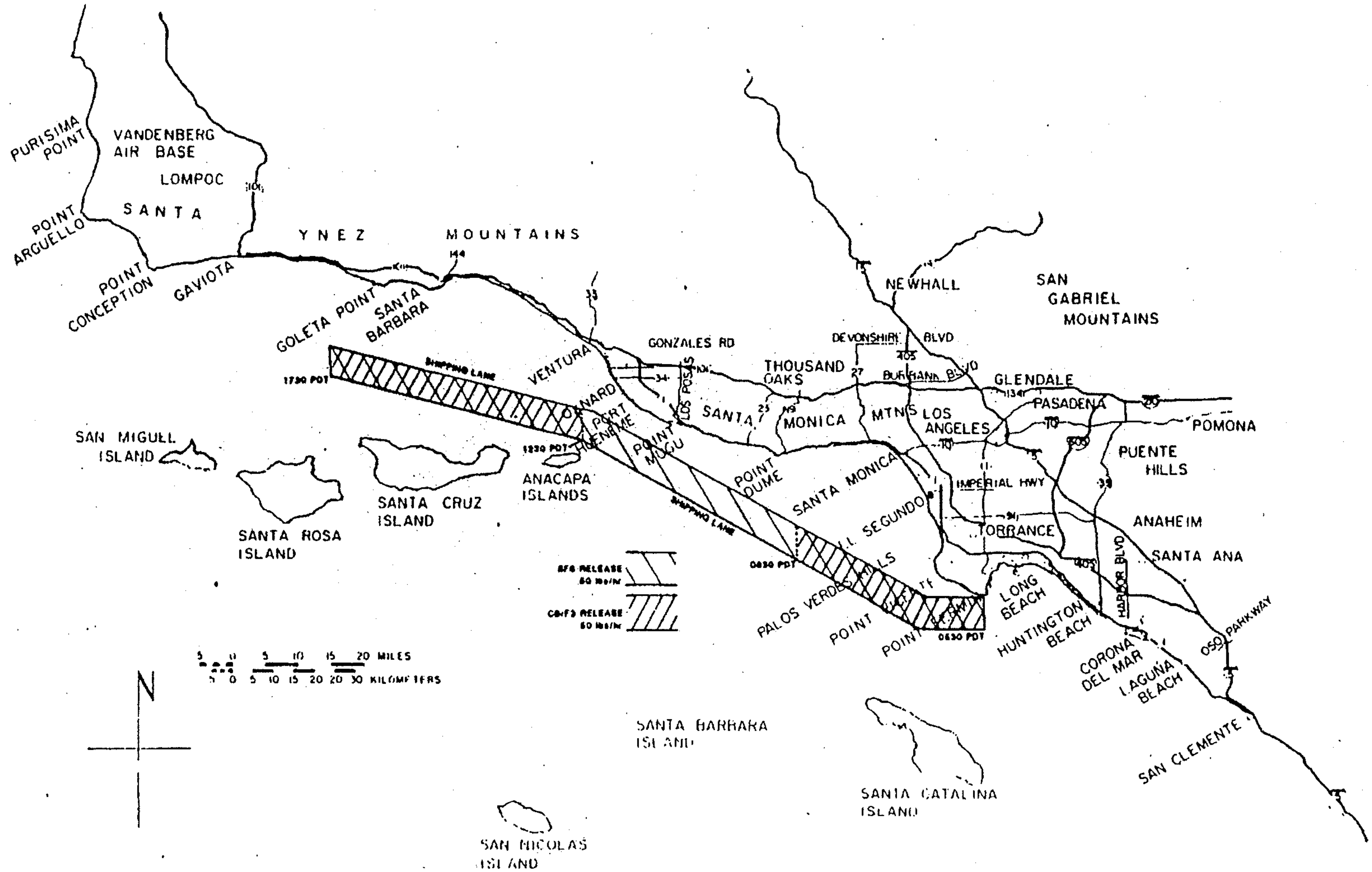


FIGURE VI-16

TRACER RELEASE DIAGRAM FOR
TRACER STUDIES OF OFFSHORE EMISSIONS

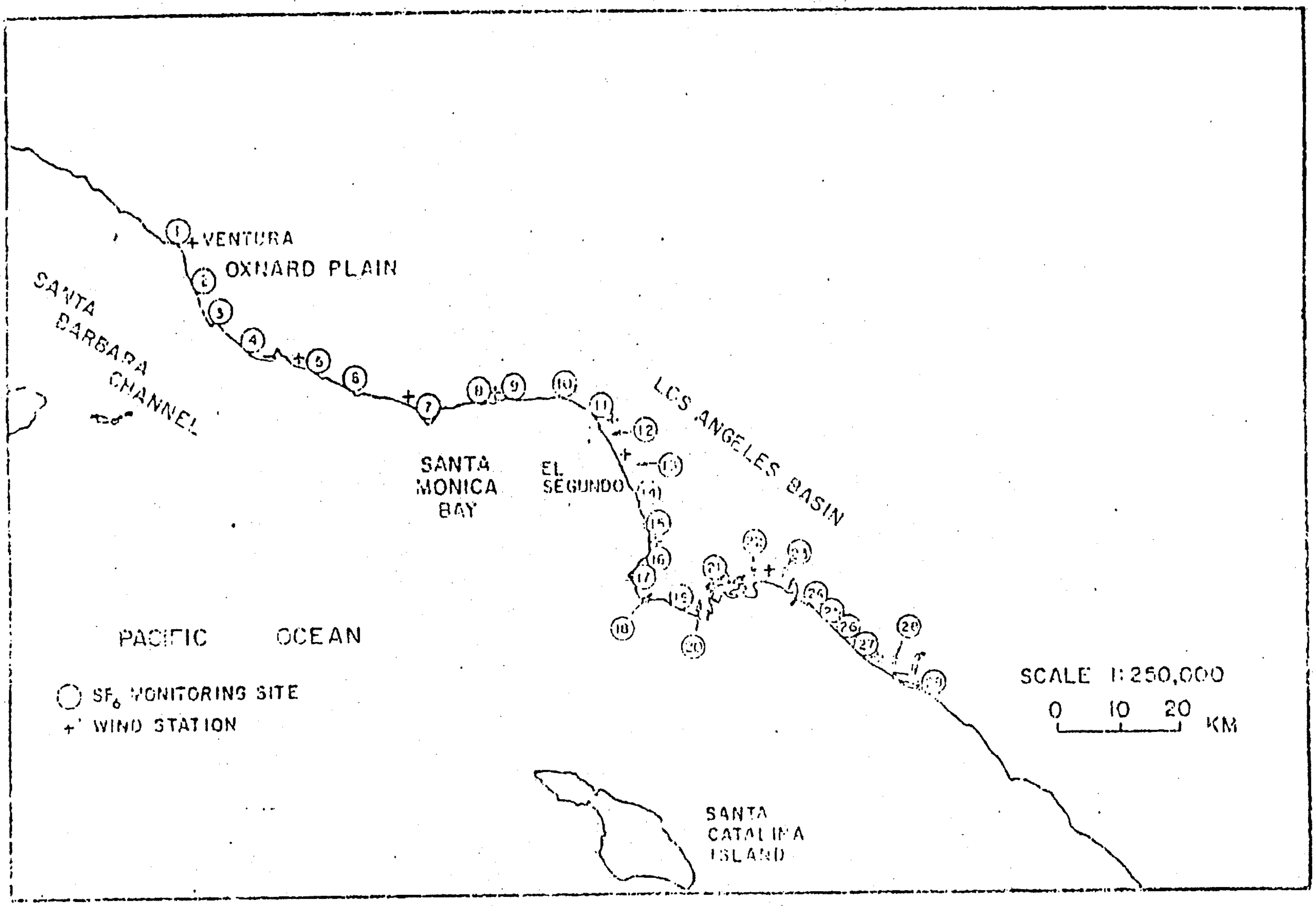


FIGURE VI-17

AIR MONITORING SITES AND
WIND STATIONS FOR TRACER STUDIES
OF OFFSHORE EMISSIONS

E. MODELING

Computer models designed to simulate, through mathematical equations, the transport, dispersion, and, sometimes, the chemical transformation of pollutants in the atmosphere can be used to estimate shoreside concentrations of pollutants released offshore. However, due to inadequate modeling formulation or lack of input data, models can predict concentrations of pollutants appreciably different from measured values. In this report, the demonstration of onshore transport of offshore emissions is based on tracer studies and meteorological analyses.

A series of screening modeling exercises were performed by the ARB staff and by Environmental Research & Technology, Inc. (ERT) to identify the upper limit of air quality impacts of sulfur dioxide emissions on receptors in the South Coast Air Basin. The ERT modeling was performed under a contract from the Western Oil and Gas Association. Three separate scenarios were modeled by the ARB staff: (1) emissions from vessels within the Ports of Los Angeles and Long Beach; (2) emissions from a single ship moving northwest along the coast; and (3) emissions from a tanker unloading at El Segundo. ERT also modeled scenarios (2) and (3). Both the ARB staff and ERT used Gaussian air quality models and considered shoreline fumigation conditions to determine the maximum one-hour onshore concentrations of sulfur dioxide. For offshore sources, it was assumed that a plume traveled from a source (ship's stack) to the coastline under stable conditions. At the coastline, erosion of the inversion layer often begins due to the thermal heating of the ground surface resulting in fumigation. The dispersion coefficients used by the ARB staff and ERT, although different, are based on studies of atmospheric dispersion over water. The ARB staff relied on the study results presented in a report prepared by the California State Lands Commission (1982)[32] while ERT relied on results reported by Schacher, et al. (1982).[33] Details of the ARB staff and ERT's modeling analyses are presented in Appendices F-1 and B-4 respectively. The following briefly describes the results of the ARB and ERT modeling analyses.

The one-hour air quality analysis of emissions from ships in the Los Angeles-Long Beach harbor area, as modeled by the ARB staff, assumed an emission rate of 8.4 tons per day of sulfur dioxide for that "area source." Under a fumigation scenario, the maximum one-hour ground level sulfur dioxide concentration, above ambient levels, is estimated at 99 micrograms per cubic meter (ug/m^3). This value occurred about 1.6 miles inland from the shoreline and can be compared with the California one-hour standard of 1,310 ug/m^3. On November 18, 1983, the Board approved a new 1-hour standard for ambient concentrations of sulfur dioxide of 0.25 ppm or about 655 ug/m^3. That standard will be in effect following its approval by the Office of Administrative Law.

The emissions impact of a ship moving along the coast was modeled by both the ARB staff and ERT by assuming a continuous moving source at varying distances from the coast. The maximum onshore one-hour ground level concentration of sulfur dioxide (above ambient levels), as modeled by the ARB staff, is 7 ug/m^3. The ERT analysis shows a maximum estimated ground level sulfur dioxide concentration of 5.1 ug/m^3. The difference between the two results is attributable to differences in the turbulent parameters and model formulations used by the ARB staff and ERT.

The third scenario modeled was for a tanker unloading at Chevron's offshore terminal at El Segundo. The ARB staff analysis shows that, under fumigation conditions, the emissions from such a tanker resulted in a maximum one-hour ground level sulfur dioxide concentration, above ambient levels, of 394 ug/m^3. That value is predicted to occur 1.4 miles inland from the coastline. The ERT analysis resulted in a maximum one-hour ground level sulfur dioxide concentration, above ambient levels, of 127 ug/m^3. Again, the difference between the ARB and ERT results is attributable to differences in turbulent parameters and model formulations used by the ARB staff and ERT. The modeling performed by the ARB staff provides an upper limit estimate for the worst-case situation. ERT argues that the ARB staff applied a modeling formulation and over-water turbulent parameters that are not based on the best available theoretical and experimental information. However, the ARB staff believes that based on the offshore meteorology for worst-case conditions and the limited data bases available to characterize over-water dispersion of air pollutants, both modeling approaches are adequate for a screening analysis. The estimates presented in this report probably represent the range of the upper limits of sulfur dioxide concentrations that may occur for the conditions simulated.

The concentrations discussed above are in addition to concentrations resulting from emissions from other sources. The one-hour air quality standard for sulfur dioxide is 1,310 ug/m^3. On November 18, 1983, the Board approved a new 1-hour standard for ambient concentrations of sulfur dioxide of 0.25 ppm or about 655 ug/m^3. That standard will be in effect following its approval by the Office of Administrative Law.

F. AIR QUALITY IMPACTS OF MARINE VESSEL EMISSIONS

There are health-related air quality standards for sulfur dioxide, sulfates, total suspended particulate (TSP), and ozone in California. There is also a standard for visibility. The standards for sulfates, TSP, and ozone are frequently violated in coastal air basins. The question is, "What is the contribution of marine vessel emissions to the degradation of air quality compared to emissions from other sources?" To answer that question, we have shown that the meteorology of California's coastal areas results in emissions from marine vessels generally being transported to inland coastal areas. In addition, the results of tracer studies show that pollutants emitted by marine vessels are transported to shore during releases in meteorological regimes typical of California's coastline. To compare the relative impact of various sources, it is common to consider an air basin as a large box in which all of the pollutants become mixed. The relative impact of a particular source is determined by calculating its fractional or percentage contribution to total emissions. Table VI-8 compares sulfur dioxide emissions from all sources with sulfur dioxide emissions from marine vessels in each of the coastal air basins from San Francisco to San Diego. Table VI-8 shows that sulfur dioxide emissions from marine vessels range from 8.2 percent of total sulfur dioxide emissions in the San Diego Air Basin to 21.8 percent in the North Central Coast Air Basin, averaging 12.0 percent in the coastal air basins shown in the table. Therefore, using the box model, marine vessels would account for the same percentage of ambient sulfur dioxide and sulfate concentrations.

Because sulfur dioxide becomes, in large part, suspended particulate matter, marine vessels would contribute to ambient TSP. Assuming that one-third of visibility reduction is caused by sulfate particles, about 4 percent of visibility reduction in coastal areas is attributable to emissions from ships.

Table VI-8

COMPARISON OF AVERAGE DAILY EMISSIONS OF
SULFUR DIOXIDE FROM MARINE VESSELS WITH EMISSIONS OF
SULFUR DIOXIDE FROM ALL SOURCES IN CALIFORNIA COASTAL AIR BASINS
1979

Air Basin	Emissions of Sulfur Dioxide from All Sources	Emissions of Sulfur Dioxide From Marine Vessels	
	Tons per day	Tons per day[a]	Percent of Total
San Francisco Bay Area	195.9	26.1	13.3
North Central Coast	33.0	7.2	21.8
South Central Coast	88.8	15.7	17.7
South Coast	262.4	22.6	8.6
San Diego	55.9	4.6	8.2
All of the Above	636.0	76.2	12.0

a/ Sea lane emissions were apportioned to coastal air basins by traffic activity and by dividing the coast south of the Sonoma-Mendocino County line into 6 zones by extending to the west the air basin boundaries at the coast and ratioing the north-south distances between those extended boundaries to the total north-south distance between the Sonoma-Mendocino County line and the boundary of California and Mexico.

Source: Air Resources Board staff.

The precursors to ozone are atmospheric hydrocarbons and oxides of nitrogen. Control strategies for ozone have emphasized hydrocarbon reductions. Table VI-9 compares hydrocarbon emissions from all sources with hydrocarbon emissions from marine vessels in each of the coastal air basins from San Francisco to San Diego. Table VI-9 shows that hydrocarbon emissions from marine vessels range from 0.5 percent of the total hydrocarbon emissions from all sources in the South Coast Air Basin to 3.4 percent in the South Central Coast Air Basin, with an average in those coastal air basins of 1.0 percent. Therefore, using the box model, hydrocarbon emissions from marine vessels would account on the average for from 0.5 to 3.4 percent of ambient ozone concentrations in those coastal air basins. Hydrocarbon emissions from tankers and barges on a given day can be several times the average daily rate because of the event-related nature of emissions. Therefore, the contribution to ozone concentrations would also be several times the average daily contribution on those days. Hydrocarbons are, in substantial part, converted to suspended particulate matter in the atmosphere. Therefore, tanker and barge hydrocarbon emissions make a contribution to ambient TSP concentrations and to visibility reduction.

The foregoing contributions of sulfur dioxide and hydrocarbon emissions to air quality degradation may seem small to some readers, but it must be borne in mind that nearly all sources of emissions are very small compared to total emissions. Therefore, it is necessary to consider controls on all sources of emissions, using cost effectiveness as the criterion for regulation.

Table VI-9

COMPARISON OF AVERAGE DAILY HYDROCARBON EMISSIONS FROM MARINE VESSELS WITH HYDROCARBON EMISSIONS FROM ALL SOURCES IN CALIFORNIA COASTAL AIR BASINS 1979

Air Basin	Emissions of Hydrocarbons[a/] From All Sources	Emissions of Hydrocarbons From Marine Vessels	
	Tons per day	Tons per day[b/]	Percent of Total
San Francisco Bay Area	767	11.4	1.5
North Central Coast	106	1.7	1.6
South Central Coast	182	6.2	3.4
South Coast	1520	7.8	0.5
San Diego	277	2.3	0.8
All of the Above	2852	29.4	1.0

a/ Reactive organic gases.

b/ These are annual average hydrocarbon emissions from marine vessels. Since most emissions from marine vessels are event-related, emissions from vessels on a given day can be several times the above figures shown. In developing this table, sea lane housekeeping and breathing emissions were apportioned to coastal air basins by tanker activity and by dividing the coast south of the Sonoma-Mendocino County line into 6 zones. The 6 zones were developed by extending to the west the air basin boundaries at the coast and ratioing the north-south distances between those extended boundaries to the total north-south distance between the Sonoma-Mendocino County line and the boundary of California and Mexico.

Source: Air Resources Board staff.

Santa Barbara County APCD Comment: I have some real concerns that the loading of this particular crude or, the burning of high sulfur fuels or the blowing of boilers at these near shore marine terminals may impact more than just the reactive hydrocarbon inventory. In the coastal counties many of these marine terminals are near the residential areas and often times are less than 5000 ft. offshore. In many of our cases, it is less than a thousand feet offshore and numerous complaints are received as a result of loading vapors which contain hydrocarbons, hydrogen sulfide or mercaptans, or as a visible emission resulting from blowing of boilers or a cold start on a diesel engine.

Response: The ARB concurs with this concern.